

What is claimed is:

1. A semiconductor device having a MEMS,
- 2 comprising:
  - 3 a semiconductor substrate on which an
  - 4 integrated circuit is formed; and
  - 5 a plurality of units which are formed on said
  - 6 semiconductor substrate and comprise movable portions
  - 7 that physically move on the basis of a first electrical
  - 8 signal,
    - 9 each of said units comprising at least
    - 10 a control electrode which supplies a control
    - 11 signal for causing the movable portion to physically
    - 12 move,
    - 13 a driving circuit which outputs the control
    - 14 signal to the control electrode on the basis of the
    - 15 first electrical signal,
    - 16 a sensor electrode which detects physical
    - 17 motion of the movable portion,
    - 18 a sensor circuit which generates a second
    - 19 electrical signal corresponding to physical motion of
    - 20 the movable portion on the basis of a signal from the
    - 21 sensor electrode,
    - 22 a memory which holds an externally input
    - 23 setting value, and
    - 24 a processor which generates the first
    - 25 electrical signal on the basis of the setting value held

26 in the memory, and controls output of the control signal  
27 from the driving circuit on the basis of the generated  
28 first electrical signal and the second electrical  
29 signal, thereby controlling operation of the movable  
30 portion,

31 wherein the driving circuit, the sensor  
32 circuit, the memory, and the processor are constituted  
33 by part of the integrated circuit.

2. A device according to claim 1, wherein  
2 the movable portion includes a mirror which is  
3 rotatably coupled to a mirror substrate,

4 the mirror substrate is supported by a support  
5 member which is formed from a conductive material on  
6 said semiconductor substrate via an interlayer  
7 dielectric layer,

8 the control electrode and the sensor electrode  
9 are arranged on the interlayer dielectric layer below  
10 the mirror so as to be insulated from the support  
11 member, and

12 the mirror is arranged at a predetermined  
13 distance above the control electrode and the sensor  
14 electrode.

3. A device according to claim 2, wherein the  
2 sensor electrode is arranged outside the control  
3 electrode in a region below the mirror.

4. A device according to claim 2, wherein the  
2 control electrode is arranged outside the sensor  
3 electrode in a region below the mirror.

5. A device according to claim 2, further  
2 comprising an insulating resin protective film which  
3 covers an upper surface of the control electrode.

6. A device according to claim 2, further  
2 comprising an insulating resin protective film which  
3 covers an upper surface of the sensor electrode.

7. A method of manufacturing a semiconductor  
2 device having a MEMS, comprising the steps of:  
3 forming an integrated circuit including a  
4 processor, a memory, a driving circuit, and a sensor  
5 circuit on a semiconductor substrate;  
6 forming an interlayer dielectric layer on the  
7 semiconductor substrate;  
8 forming in a plurality of unit regions on the  
9 interlayer dielectric layer a plurality of control  
10 electrodes and a plurality of sensor electrodes which  
11 are insulated from each other;  
12 forming a support member from a conductive  
13 material on the interlayer dielectric layer so as to  
14 become higher than the control electrode;

15                   preparing a mirror substrate which comprises  
16   mirrors in a plurality of opening regions and is formed  
17   from a conductive material, the mirrors being pivotally  
18   coupled to the mirror substrate via coupling portions;  
19   and

20                   connecting and fixing the mirror substrate  
21   onto the support member to arrange the mirrors of the  
22   mirror substrate at an interval above the control  
23   electrodes and the sensor electrodes which are formed  
24   for the plurality of units,

25                   wherein the control electrodes are  
26   electrically connected to the driving circuit so as to  
27   receive a signal from the driving circuit, and

28                   the sensor electrodes are electrically  
29   connected to the sensor circuit so as to output a signal  
30   to the sensor circuit.

8.                  A method according to claim 7, wherein before  
2   the mirror substrate is connected and fixed onto the  
3   support member, a predetermined resin pattern is formed  
4   by stencil printing to form a protective film which  
5   covers at least top of the control electrode.

9.                  A method according to claim 7, wherein before  
2   the mirror substrate is connected and fixed onto the  
3   support member,  
4                  a photosensitive resin pattern which covers

5 the control electrode is formed by stencil printing, and  
6 the resin pattern is patterned by  
7 photolithography to form a protective film which covers  
8 at least top of the control electrode.

10. A method of manufacturing a semiconductor  
2 device having a MEMS, comprising at least the steps of:  
3 forming an integrated circuit including a  
4 processor, a memory, a driving circuit, and a sensor  
5 circuit on a semiconductor substrate;  
6 forming an interlayer dielectric layer on the  
7 semiconductor substrate;  
8 forming in a plurality of unit regions on the  
9 interlayer dielectric layer a plurality of control  
10 electrodes and a plurality of sensor electrodes which  
11 are insulated from each other;  
12 forming a support member from a conductive  
13 material on the semiconductor substrate via an  
14 insulating film so as to become higher than the control  
15 electrode;  
16 forming a mirror substrate from a conductive  
17 material on the support member while holding a space  
18 above the control electrodes and the sensor electrodes;  
19 and  
20 forming, in the plurality of unit regions,  
21 opening regions which pass through the mirror substrate,  
22 and forming, in the opening regions, mirrors which are

23 pivotally coupled to the mirror substrate via coupling  
24 portions,

25 wherein the mirrors formed on the mirror  
26 substrate in the unit regions are arranged at an  
27 interval above the control electrodes and the sensor  
28 electrodes,

29 the control electrodes are electrically  
30 connected to the driving circuit so as to receive a  
31 signal from the driving circuit, and

32 the sensor electrodes are electrically  
33 connected to the sensor circuit so as to output a signal  
34 to the sensor circuit.

11. A method of manufacturing a semiconductor  
2 device having a MEMS, comprising the steps of:  
3 forming an integrated circuit including a  
4 processor, a memory, a driving circuit, and a sensor  
5 circuit on a semiconductor substrate;  
6 forming on the semiconductor substrate an  
7 interlayer dielectric layer which covers the integrated  
8 circuit;  
9 forming a seed layer on the interlayer  
10 dielectric layer;  
11 forming on the seed layer a first sacrificial  
12 pattern having openings in a first region, a plurality  
13 of second regions, and a plurality of third regions;  
14 forming on the seed layer exposed in the

15    first, second, and third regions a first metal pattern  
16    substantially equal in film thickness to the first  
17    sacrificial pattern by plating, and a second metal  
18    pattern and a third metal pattern not larger in film  
19    thickness than the first metal pattern;

20                after forming the first, second, and third  
21    metal patterns into predetermined film thicknesses,  
22    forming on the first sacrificial pattern and the second  
23    and third metal patterns a second sacrificial pattern  
24    having an opening in a fourth region on the first metal  
25    pattern;

26                forming a fourth metal pattern substantially  
27    equal in film thickness to the second sacrificial  
28    pattern by plating on a surface of the first metal  
29    pattern that is exposed in the fourth region;

30                after forming the fourth metal pattern into a  
31    predetermined film thickness, removing the first and  
32    second sacrificial patterns;

33                after removing the sacrificial patterns,  
34    selectively removing the seed layer by using the first,  
35    second, and third metal patterns as a mask, thereby  
36    forming a support member from a layered structure of the  
37    first and fourth metal patterns, a plurality of control  
38    electrodes which are formed from the plurality of second  
39    metal patterns and separated from each other on the  
40    interlayer dielectric layer, and a plurality of sensor  
41    electrodes which are formed from the plurality of third

42 metal patterns and separated from each other on the  
43 interlayer dielectric layer;  
44 preparing a mirror substrate which comprises  
45 mirrors in a plurality of opening regions and is formed  
46 from a conductive material, the mirrors being pivotally  
47 coupled to the mirror substrate via coupling portions;  
48 and  
49 connecting and fixing the mirror substrate  
50 onto the support member to arrange the mirrors of the  
51 mirror substrate at an interval above the control  
52 electrodes and the sensor electrodes,  
53 wherein the control electrodes are  
54 electrically connected to the driving circuit so as to  
55 receive a signal from the driving circuit, and  
56 the sensor electrodes are electrically  
57 connected to the sensor circuit so as to output a signal  
58 to the sensor circuit.

12. A method according to claim 11, wherein before  
2 the mirror substrate is connected and fixed onto the  
3 support member, a predetermined resin pattern is formed  
4 by stencil printing to form a protective film which  
5 covers at least top of the control electrode.

13. A method according to claim 11, wherein before  
2 the mirror substrate is connected and fixed onto the  
3 support member,

4               a photosensitive resin pattern which covers  
5   the control electrode is formed by stencil printing, and  
6               the resin pattern is patterned by  
7   photolithography to form a protective film which covers  
8   at least top of the control electrode.

14.           A method of manufacturing a semiconductor  
2 device having a MEMS, comprising the steps of:  
3               forming an integrated circuit including a  
4 processor, a memory, a driving circuit, and a sensor  
5 circuit on a semiconductor substrate;  
6               forming on the semiconductor substrate an  
7 interlayer dielectric layer which covers the integrated  
8 circuit;  
9               forming a seed layer on the interlayer  
10 dielectric layer;  
11              forming on the seed layer a first sacrificial  
12 pattern having openings in a first region, a plurality  
13 of second regions, and a plurality of third regions;  
14              forming on the seed layer exposed in the  
15 first, second, and third regions a first metal pattern  
16 substantially equal in film thickness to the first  
17 sacrificial pattern by plating, and a second metal  
18 pattern and a third metal pattern not larger in film  
19 thickness than the first metal pattern;  
20              after forming the first, second, and third  
21 metal patterns into predetermined film thicknesses,

22 forming on the first sacrificial pattern and the second  
23 and third metal patterns a second sacrificial pattern  
24 having an opening in a fourth region on the first metal  
25 pattern;

26 forming a fourth metal pattern substantially  
27 equal in film thickness to the second sacrificial  
28 pattern by plating on a surface of the first metal  
29 pattern that is exposed in the fourth region;

30 after forming the fourth metal pattern into a  
31 predetermined film thickness, forming on the second  
32 sacrificial pattern a mirror substrate which is  
33 electrically connected to the fourth metal pattern and  
34 formed from a conductive material;

35 forming a through hole in the mirror  
36 substrate, and forming in a plurality of predetermined  
37 regions of the mirror substrate a plurality of mirrors  
38 which are pivotally coupled to the mirror substrate via  
39 coupling portions;

40 removing the first and second sacrificial  
41 patterns via the through hole formed in the mirror  
42 substrate; and

43 after removing the sacrificial patterns,  
44 selectively removing the seed layer via the through hole  
45 by using the first, second, and third metal patterns as  
46 a mask, thereby forming a support member from a layered  
47 structure of the first and fourth metal patterns, a  
48 plurality of control electrodes which are formed from

49 the plurality of second metal patterns and separated  
50 from each other on the interlayer dielectric layer, and  
51 a plurality of sensor electrodes which are formed from  
52 the plurality of third metal patterns and separated from  
53 each other on the interlayer dielectric layer,

54 wherein the mirrors formed on the mirror  
55 substrate are arranged at an interval above the control  
56 electrodes and the sensor electrodes,

57 the control electrodes are electrically  
58 connected to the driving circuit so as to receive a  
59 signal from the driving circuit, and

60 the sensor electrodes are electrically  
61 connected to the sensor circuit so as to output a signal  
62 to the sensor circuit.